The subsea gate box: an alternative subsea field architecture

The process of planning and developing an offshore hydrocarbon field is normally based on very limited information collected from exploratory wells and making proper assumptions on the reservoir characteristics. The uncertainties in the subsurface, in the development process and during the regular operations on the field production are an important challenge to overcome for the different disciplines involved. New constraints, changes in the operating conditions or new discoveries could lead to significant deviation from the initial forecast. Therefore, system flexibility is paramount not only for daily operations but also to enable adapting and upgrading the subsea facilities according to varying requirements and conditions of the field.

Production management and optimization are crucial in subsea developments where each well, equipment and marine operation are considerably more expensive than for standard onshore fields. Therefore, field architecture concepts should allow a higher degree of flexibility in the well production and to increase production management capabilities.

On this line of thinking, the Subsea Gate Box Concept has been proposed as an alternative to integrate subsea processing on the field architecture, aimed to increase flexibility and efficiency. The concept is an ongoing study within SUBPRO research center, which is an SFI project founded by the Research Council of Norway, the Norwegian University of Science and Technology and different industrial partners from diverse sectors of the oil and gas industry. SUBPRO, "Subsea Production and Processing", is mainly focused on five core areas of the subsea production system: separation concepts, flow characterization, system control, field architecture, and reliability and safety. SUBPRO primary objective is to provide the oil & gas industry with knowledge and technology innovation within subsea production and processing.

The Subsea Gate Box (SGB) is addressed to oil and gas fields with large heterogeneity among wells that might be due to different formations or reservoirs with very different properties and conditions. In standard field architectures, it is common to comingle the production of the different wells prior to pre-processing and transport. Such strategy might lead to a mismanagement of the naturally available energy and make it difficult to keep high efficiency of the process equipment. For instance, commingling wells with different reservoir pressures and productivities requires to choke-back the stronger wells to match the capacity of the low energy wells. In other words, the weaker wells are the ones dictating the wellhead pressure and, thus, the production. Moreover, the system might become constrained by wells with less favorable conditions (higher gas fraction, water cut, stream pressure, fluid composition, hydrate formation, waxes, etc.), or require very wide operational ranges for subsea processing units such as boosters and separators.

It is possible to design subsea processing units for wide operational conditions, but it requires large and more robust equipment, which might frequently work outside of their optimal operating envelope, thus wasting energy. Although the equipment footprint is not a constraint subsea, it is for the installation and maintenance of such units. Furthermore, deep-water applications require even more robustness to withstand high pressures, adding extra challenges from a manufacturing perspective. Therefore, modular and compact process units are gaining attention also for subsea developments.

Robustness is not only required from the hardware point of view but it also an important factor in the development of numerical models. In the current digitalization era, optimization of the production also relies on the capacity of the models to predict the different phenomena, from the reservoir dynamics and flow assurance issues within the network, to prognostics model for control and maintenance purpose. Hence, the gate box concept could potentially contribute to increase confidence in the process system performance and its management capability, enabling higher accuracy and applicability of numerical models on the prediction of a given process or equipment.

The subsea gate box has been defined as a multifunctional assembly that enables decoupling the well performance from the network by incorporating process modules to to prepare the wells stream to be introduced into the production system. The assembly would consist of retrievable modules for dedicated process trains, which could include separation, boosting, chemical injection, metering, among other auxiliary processes to improve the well performance. In principle, these individual trains only would contain primary stages of a given process. The ultimate objectives are to prepare the well stream for further processing and optimize the usage of both the reservoir energy and the external energy introduced to the fluid stream while avoiding reducing production.

“The Subsea Gate Box (SGB) is addressed to oil and gas fields with large heterogeneity among wells”

The SGB could be designed for different field architectures including satellite wells, clusters, and template configurations. Each module will give

Mariana J.C. Diaz,
Postdoctoral Fellow SUBPRO /NTNU
mariana.j.diaz@ntnu.no

the opportunity to adapt the process train to the specific operating conditions of an individual well or group of wells over the lifetime of the field. In this way, the different equipment could be designed for a more optimal operational range, potentially enabling higher process efficiency and smaller footprint per unit. The subsea gate box concept opens the opportunity for increasing the flexibility in the production system along the network and over the lifetime of the field. The assembly could easily allow for future modifications of the subsea system and redundancy for critical processes. The modules should be easily retrievable for replacement or upgrading of units using regular intervention vessels. As an example, a diagram of the SGB concept is shown in Figure 1. Assuming a given field development that includes different formations and reservoirs, all of which are developed on different project stages over the time. A well or a group of wells could present different performance and/or very different flow characteristics, from fluid composition to different water cut or gas fraction. A dedicated processing train could be designed to attend the different well fluids and operating conditions. Thus, a given train could contain units for separation or flow conditioning, liquid boosting and gas treatment, while another train could only contain some chemical treatment and leave some free slots for future modifications or upgrades. Furthermore, the trains could be interconnected among them to allow bypassing production from one train to another, as a means to increase redundancy or increase operational flexibility during maintenance procedures.

> “ The subsea gate box concept opens the opportunity for increasing the flexibility in the production system ”

The main drawback of the concept lies on the increasing number of components and the increasing complexity of the system in terms of electrical and flow connections. Therefore, an important task on the concept evaluation would be to define the feasibility of the application of such assembly in terms of the cost-effective impact of the SGB and the reliability and availability of the major components. The analysis related to RAMS will be considered on a separate project within SUBPRO,

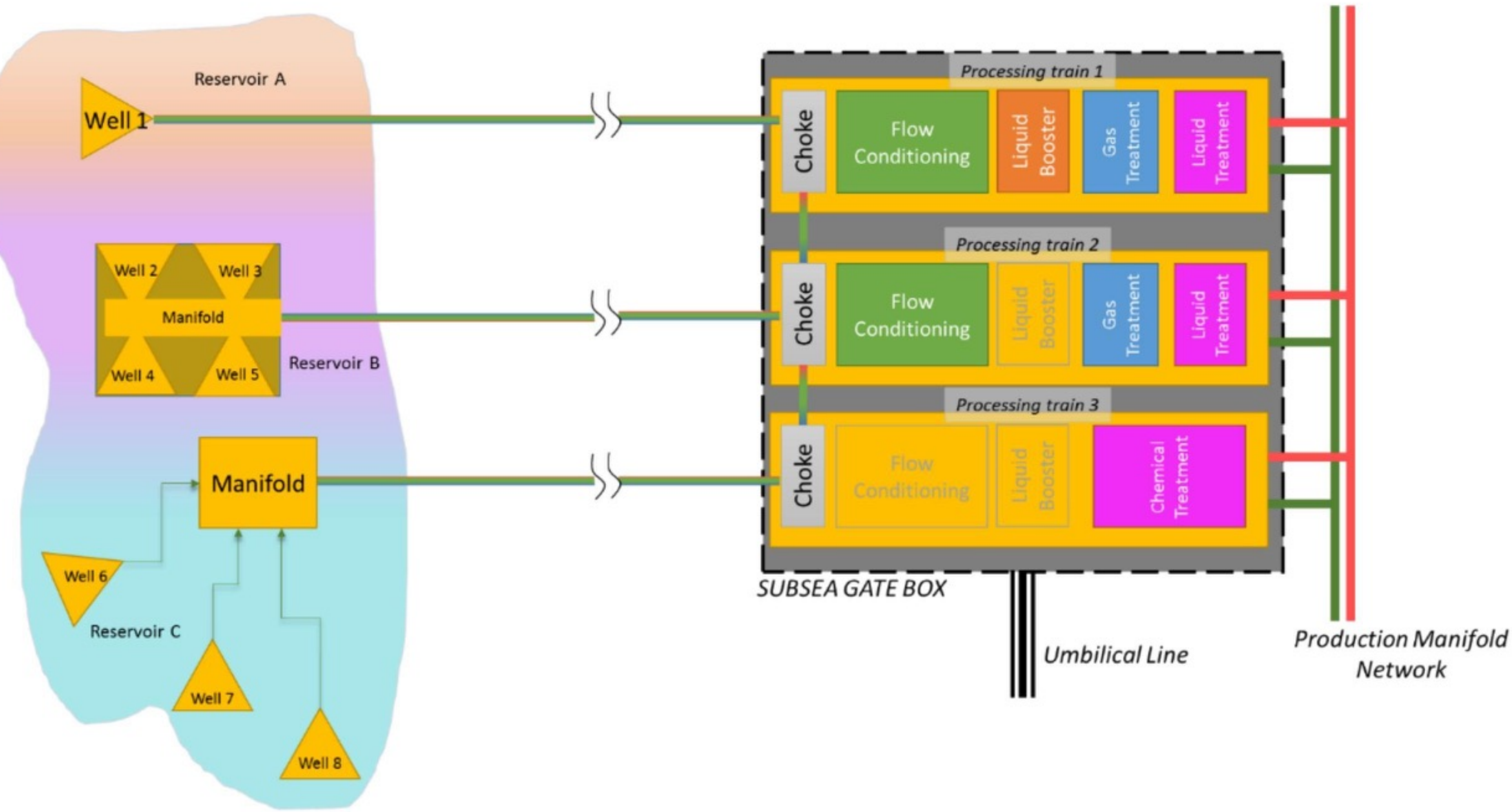

Figure 1 Subsea Gate Box Concept

where the Subsea Gate Box will be used as an example for including reliability analysis on the early design of subsea systems. The cost-effective evaluation, on the other hand, would be carried out in three stages. The first stage includes defining the niche of application for the concept and identifying the scenarios where the SGB would give the best benefit. The second stage is the identification of the technology available in the market or under development that could potentially be used within the SGB, mapping the current gaps in equipment and technology. The final stage is when the concept proposal, which includes looking at possible suitable configurations and arrangements

Sigbjørn Sangesland,
Professor Department of Geoscience and Petroleum NTNU

that could be used in the SGB to provide easiness to connect and remove equipment and customizable units.

The objective was to evaluate the capability of the gate box concept by including liquid boosting within the modular assembly.

The simulations showed the possibility to increase production from a target well by 24% when applying the subsea gate box concept with respect to the production achieved by a central boosting configuration. Thus, the results have been encouraging for the subsea gate box concept and they have shown some potential for the application of such strategy.

Future work will focus on defining the main functional characteristics and requirements of the gate box, as well as performing a rough economic evaluation of such concept. Further analysis may consider the value of the flexibility against the complexity of the system.

“The simulations showed the possibility to increase production from a target well by 24% ”

Furthermore, the concept proposal stage would explore the cost implications and benefits of the concept for subsea developments.

The first stage has been carried out based on a synthetic business case of a typical oil field development. The analysis has included numerical simulations using a commercial software for integrated modeling of a production system.

This aspect could represent one of the key element on the incorporation of such concept as a plausible alternative for a given subsea development.

Likewise, including optimization of the field architecture design and operational strategy might be important in order to ensure a fair comparison of the Subsea Gate Box concept respect the existing solutions.

Milan Stanko,
Associate Professor Department of Geoscience and Petroleum.
NTNU

Acknowledgment
This work is a part of SUBPRO, a Research-based Innovation Centre within Subsea Production and Processing. The authors gratefully acknowledge the financial support from SUBPRO, which is financed by the Research Council of Norway, major industry partners, and NTNU.

Authors:
Mariana J.C. Diaz, Postdoctoral Fellow SUBPRO /NTNU
Sigbjørn Sangesland, Professor Department of Geoscience and Petroleum NTNU
Milan Stanko, Associate Professor Department of Geoscience and Petroleum. NTNU